Vertical Profile (Temperature and Conductivity) and Surface Currents at Cage Culture Non – Cage Culture Area in Batang Ai Hydroelectric Dam Reservoir, Sarawak.

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Declaration

I hereby declare that the work of my project is my own except for the quotations, citations and summaries in which have been duly acknowledge. No portion of the work referred to in this dissertation has been submitted in support of an application for another degree qualification of this or any other university or institution of higher learning.

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If you hear a voice within you say,

You cannot paint, then by all means paint,

And that voice will be silenced

- *Vincent van Gogh* -

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List of Abbreviation

ANOVA	Analysis of Variance
^{o}C	Degree celcius
CM	Current Meter
CTD	Conductivity Temperature Density
GPS	Global positioning satellite
km	Kilometer
m	Meter
cm/s	centimetre per second
N	North
µS	micro Siemen

Vertical Profile (Temperature and Conductivity) and Surface Currents in Non – Cage Culture and Cage Culture Area at Batang Ai Hydroelectric Dam Reservoir.

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Batang Ai Hydroelectric Dam Reservoir is a first man – made lake in Sarawak. Although the water quality in Batang Ai Hydroelectric Dam Reservoir have been assessed yearly but there is less scientific studies on surface waters and the vertical profile of temperature and conductivity at selected Cage Culture area and Non – Cage Culture of Batang Ai Hydroelectric Dam Reservoir. Therefore, the objective of this study was to identify and illustrate the vertical profile of temperature and conductivity at Cage Culture and Non – Cage Culture Area of Batang Ai Hydroelectric Dam Reservoir. Moreover, to elucidate the surface waters using Current Meters.. In this study, 24 stations were servey for profiling of stratification of temperature and conductivity; 13 stations were conducted for surface current. Results show there were significant dropped in temperatures for all stations range from 24.9 to 32.2 ^{0}C from Epilimnion to Hypolimnion Layer ($P<0.05$). Meanwhile, vertical profile of conductivity fluctuated; increasing with depth as from Eplimnion reaching out to Hypolimnion. There was significant higher in conductivity in Cage Culture Area compared to Non – Cage Culture Area ($P<0.05$). Hypolimnion layer hold the highest conductivity of all layers. As for surface current, it was found that the mean of surface current was 42.15 ± 19. 96 cm/s. Circulated in a clockwise manner as influenced by the Coriolis's effect and prevailing wind of trade. This study could help to provide the robust management tools for aquaculturist and management.

Keywords: reservoir, Batang Ai, hydrodynamic, vertical profile, temperature, conductivity

Batang Ai Hydroelektrik Dam ialah tasik buatan pertama di Sarawak. Walaupun status tahunan kualiti air di Batang Ai Hydroelektrik Dam telah diukur, namun kurangnya kajian saintific keatas arus di permukaan and profil menegak untuk suhu dan conduktiviti di kawasan pemeliharaan ikan bersangkar dan kawasan tiada pemiliharaan ikan bersangkar di Batang Ai Hydroelectric Dam. Oleh kerana itu, objektif untuk kajian ini ialah untuk mengenal pasti dan memaparkan profil menegak untuk suhu dan conduktiviti di kawasan pemiliharaan bersangkar dan bukan kawasan bersangkar. Seterusnya, mengenalpasti arus permukaan menggunakan meter arus. Dalam kajian ini, 24 stesen telah diuji untuk profil strastifikasi untuk suhu dan conduktivi.; 13 stesen pula diuji untuk arus permukaan. Hasil kajian menunjukkan terdapat kejatuhan yang ketara keatas semua station dari 24.9 ke 32.2 ^{0}C dari permukaan Epilimnion dan Hypolimnion. Manakala, profil menegak untuk conduktiviti didapati trend naik turun; meningkat depan kedalaman dari lapisan Epilimnion ke Hypolimnion. Terdapat perubahan ketasa dalam conduktiviti di kawasan pemeliharaan ikan bersangkar dan tiada sangkar ($P<0.05$). Lapisan Hypolimnion ialah lapisan yg paling tinggi untuk conduktiviti. Seterusnya untuk arus permukaan bergerak sebanyak 42.15±19.96 cm/s. Arus permukaan bergerak mengikut arah putaran jam yang di pengaruhi oleh Coriolis's eefect and angin. Kajian ini mungkin boleh memberikan teknik pengurusan yg telus untuk pengusaha sangkar ikan.

Kata Kunci: Takungan Air, Batang Ai, hydrodinamik, profil menegak, suhu, conduktiviti

1.0 Introduction

Reservoirs are mainly built by damming rivers either for hydroelectricity generation or for irrigation (Madhav K. Shrestha *et al*, 1999) such as Batang Ai Hydroelectric Dam Reservoir, Sarawak. It was built in 1985 as Sarawak first man – made reservoir and been operation since then. On the other hands, for over 18 years Batang Ai Hydroelectric Dam Reservoir was claimed as freshwater cage culture (Nyanti L. *et al*, 2012) as most cage culture is set up in rivers, lakes and the sea (Beveridge, 1984).

Even though, cage culture has long been practised in Southeast Asia (Ling. S. W, 1977; Kwei Lin. C *et al*, 1993), still it was first introduced in a small scale in Batang Ai Hydroelectrical Dam Reservoir. With time, freshwater cage culture industry keep expanding due to high demand from the market and tilapia is the main fish species cultured (Nyanti L. *et al*, 2012). The increasing of cage culture in Batang Ai Hydroelectric Dam Reservoir might lead to several impacts on the reservoir and also surrounding waters.

This is because in many cases the fishes are fed with high protein diets in intensive cage culture and waste derived from the feed are either directly or indirectly released to the surrounding environment, causing the accelerated eutrophication in those waters.

As reported worldwide especially in Indonesia in Cirata lake (Prihadi. T. H., 2005), intensive cage culture that exceeding the carrying capacity of the reservoir causing environmental impact such as eutrophication and anoxic water.

One of the common factors that contributed in the eutrophication and anoxic water in most reservoirs is the movement of the surface waters. Traditionally, frequent water change is required in intensive fish culture ponds as it to maintain the desirable water quality (Kwei Lin. C., *et al*,1993).

However, in reservoir it happens differently because it hold so little of exchange in water volume which only depend on input of the waters from the nearest river and also

storms or heavy rains that will bring more volume of waters (Kolumban Hutter *et al,* 2011) into dam. This will cause the nutrient or waste products to be accumulated for certain period of time till it being irrigated.

These anthropogenic inputs are likely to be settled down at the bottom of the lake called hypolimnion layer. Hypolimnion layer are separated with metalimnion layer and epilimnion layer by a layer of thermocline. In general, thermocline is the layer where the sudden drop of temperature occurs.

In temperate regions, thermocline layer is influenced by the seasonal. But as for tropical body water such Batang Ai Hydroelectric Dam Reservoir, prevailed wind and heavy storm influencing the layer and as it happen, the mixing occurs or known as turnover. As turnover event happen, the anoxic waters which is settled down at the hypolimnion layers will rises to the surface water caused water become anoxic can killed the fishes.

Although the water quality in Batang Ai Hydroelectric Dam Reservoir have been assessed yearly but there is less scientific studies on hydrodynamic of surface waters and the vertical profile of temperature and conductivity at selected freshwater cage culture of Batang Ai Hydroelectric Dam Reservoir.

The objective of this project:-

1. To identify and illustrate the vertical profile of temperature and conductivity at selected freshwater cage culture of Batang Ai Hydroelectric Dam Reservoir.
2. To elucidate the features of surface waters using Current Meters.

2.0 Literature Review

This section will be talking about the vertical profile of temperature, conductivity, hydrodynamic, turnover event and the history of the Batang Ai Hydroelectric Dam Reservoir

2.1 Batang Ai Hydroelectric Dam Reservoir

2.1.1 History

Batang Ai Hydroelectric Dam Reservoir is the first man – made reservoirs and hydroelectric dam in Sarawak. It was completed in 1985 with river diversion starting in 1982 (Al – Zulbaidy & Rigit, 1997). Located in Sri Aman region about 250 km off Kuching, this artificial lakes extend from the Skrang, Lemanak, Engkari and Ai Valley.

As Vilhena L. C (2011) claimed that Batang Ai Hydroelectric Dam Reservoirs is deep enough to exhibit representative it stratification patterns. The maximum height of the dam's foundation is about 110 meters and the permissible volume of flow of waters range from 40 to 45 $m^3 s^{-1}$. It is a tropical reservoir with a catchment area of 1200km^2.

2.1.2 Cage Culture

Cage culture can be practised intensively, semi – intensively or extensively. The intensity of operations depends mainly on the economics and the availability of the fingerlings and feeds. Most cage culture is set up in rivers, lakes and the sea (Beveridge, 1984)

According to Newton's third law of motion, when one body exerts a force on a second body; the second body simultaneously exerts a force equal in magnitude and opposite in direction of the first body (Benjamin Cowell, 2000). In simple words when too much forces or stresses are put into a certain system, the system itself will give out an opposite force or stress which is oppositely to each other.

This is usually happen in most intensive cage culture around the world, due to the carrying capacity (will be discussed in later sub – topic) of the system itself cannot withstand the stress. Eventually the system give arise to environmental issues such as nutrient eutrophication and anoxic water. In this context, the system is the reservoirs and the stress is existed as the accumulation of the anthropogenic inputs such excess waste and uneaten feed that come from the cage culture.

Several cases documented in Laguna de Bay, Philipine in early 1980's (Barica, 1976; Beveridge, 1984) and in Cirata Reservoir, Indonesia (Costa –pierce, 1998; Abery *et al*., 2005; Prihadi, 2005; Hayami *et al*., 2008; Nyanti L. *et al*., 2012) result in the fishes are kills due to unsustainable development of cage culture in reservoirs.

2.1.3 Batang Ai Hydroelectric Dam Reservoir as freshwater cage culture

For over 18 years, Batang Ai Hydroelectric Dam Reservoir was claimed as aquaculture farms for red tilapia. According to Beveridge (1996), cage culture is an activity that involved the rearing of animals in structures that enclosed on all, but the top sides by wooden, mesh or even net screens, while maintaining a free movement of waters.

Aquaculture in lakes and reservoirs are often seen as money generator, as well as providing employment, foods and support for local communities. In generals, the cage culture has some distinctive advantages compared to other fish culture methods. Some of the advantages for having cage culture are short period of fish harvesting time and low capital cost is required. This encourages aquaculture and fisheries industry to be developed in the Batang Ai Hydroelectric Dam Reservoir.

At first, this newly introduce economy generator are not well recognize by the stakeholders but as increases in demand of animal protein in local markets from low production of 3 tons in 1993 increased to 434 tons in 2003 and 744 tons in 2011 (Nyanti. L. *et al*,2012) lead to economy boom to the surrounding area.

However, it also has disadvantages too. Now in year of 2015 more cage culture will be builds in the reservoirs to support the demand from market which will give a rise to several environmental issues. As stated by Beveridge *et al.*,(1991;1997), intensive cage culture when unregulated can cause severe environmental problems.

Figure 1: Nutrient input to Lake System through fish pallets given by breeder. (retrieved from http://www.ableasiaaquaculture.com)

2.2 Mixing in Lakes and Reservoirs

Mixing in lakes and reservoirs is largely controlled by stratification. Stratification arises from temperature, dissolved solids and suspended variations. In this study the thermal stratification is the main priority. Stratification is dominantly dependent on temperature variation. In turn, it is act as function of the overall energy balance and the internal mixing processes of lakes that usually happens in temperate countries. As for tropic countries prevailed wind, heavy storms or sudden flow of waters into waters body of reservoirs is the main contributor in mixing processes.

2.2.1 Vertical Stratification

Vertical stratification is a powerful tool for understanding on lakes behaviour in terms of chemistry, physics and biology (Dodson Stanley, 2005). As stratification is the study of the layers include physical hydrology characteristics of a water bodies and it is influence by morphometrical parameters such as surface area and depth (Gorham & Boyce, 1989). Vertical profiles of temperature of Batang Ai Hydroelectric Dam Reservoir were investigated in this study.

In generals, most tropic lakes and reservoirs had 3 distinctive layers. The first layer is called epilimnion. It is a layer that located at the upper layer of the water body or also known as surface water. At this layer, the temperature is the highest among all layers as it exposed to direct sunlight and the wind drift directly making contact with this layer.

The second layer is metalimnion, and thermocline layers exist here. Thermocline is the layer of rapid change in temperature (Sundram T. R & Rehm R. G. , 1972). This thermocline layer is the layer that holds up the hypolimnion layer. A layer with low Dissolved Oxygen (DO), no illumination and anoxic waters accumulated in this layer.

This thermocline layer is a big concern to aquaculturist because when the mixing occurs or know as turnover event (will be explain in later sub – topic) occurs the thermocline layer breakdown. The waters from Hypolimnion layer will mix up with surface water in results killed the fishes inside the cage culture.

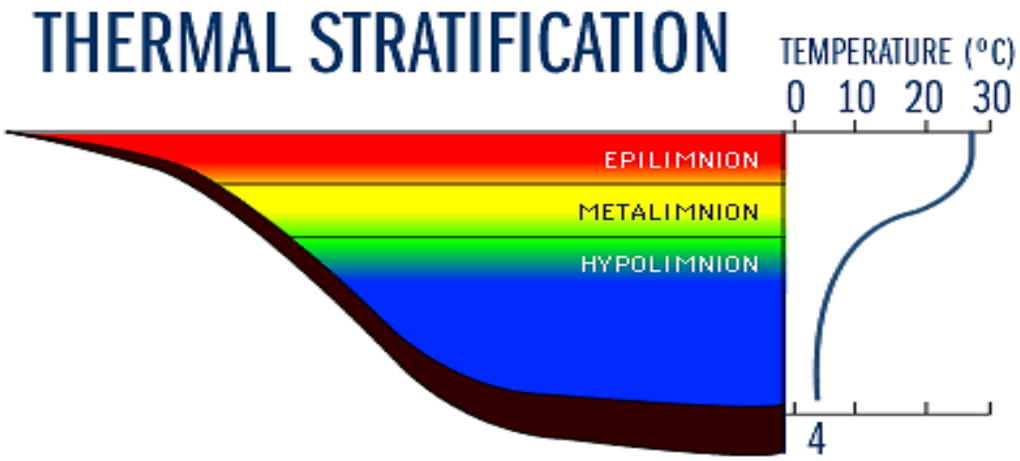

Figure 2: Layers of zonation in typical tropic lakes and dams (retrieved from http://www.waterontheweb.org/under/lakeecology/05_stratification.html).

2.2.2 Turnover Event

In temperate countries, turnover event is influenced by the seasonal cycle of lakes or dams. Special for tropic countries like Malaysia, she does not experience the four seasons as she located near the equator. In the lowland Tropics such Indonesia and Malaysia, the dams and lakes is influence by the wind actions that stir the water column from the top to bottom (Costa – Pierce, 1997).

In temperate countries, the turnover events usually happens twice annually; fall turnover and spring turnover. Lakes that experience this full cycle are called dimictic (which will not be discussed in this study).

Sudden turnovers in reservoirs can led to catastrophic in fish kills (Costa – pierce, 1997); as the thermocline breakdown causing the deoxygenated water and large quantities of hydrogen sulphide that rise to the surface water suffocated nearly all aquatic life.

Indonesia is famous for aquaculture in South East Asia; located near to the equator line, shared the same distinctive characteristic as Malaysia. The characteristic of body waters of this country are believed to be the same as ours. Indonesia has two distinct seasons; it is determined by its prevailing wind patterns; a dry season from April and August and a wet season from September to March.

Case study in Saguling and Cirata Reservoir in Indonesia (Effendi, 1992; Sutandar, 1993; Costa – pierce, 1997;Hayami *et al*., 2010) documented showed the turnovers had several characteristic.

Observation of turnovers in Saguling showed the following characteristics:

1. Turnover varied across the reservoir, occurring in one bay but not the others.
2. Some turnovers seemed to be caused by the entry at the onset of the wet season, water with low temperature intrude and cause bottom water to be displaced rather than surface cooling.
3. Strong drawdowns during the rainy season influence the turnovers frequency.
4. Turnovers were followed by dense, blue – green algal bloom because of the movement of bottom nutrient to the surface.

2.3 Carrying capacity

Every system had their unique carrying capacity. As this carrying capacity which determine the system vulnerability. According to the Oxford Dictionary in terms of ecology, carrying capacity can be defined as the numbers or quantity of things which a region can support without environmental degradation.

In this context, the region is the body of waters and the quantity is the aquaculture units. Long story cut short, there is a limit to the numbers of aquaculture activities that a body of water of Batang Ai Hydroelectric Dam Reservoir can support before it started to break apart and pollute the surrounding waters. Hence, the productivity of aquaculture activities will be reduced.

It is to be believed that the carrying capacity will quickly to be reached by intensively managed units receiving large amounts of high – protein. It all depend on the types of practises that being practise or will be practise and hydrodynamic of surface current in Batang Ai Hydroelectric Dam Reservoir.

2.4 Hydrodynamic

2.4.1 Importance of Hydrodynamic in Lakes and Dams

Hydrodynamic such as surface current play an important roles in the exchanges of water in reservoirs such as Batang Ai Hydroelectric Dam Reservoir. Surface current usually takes place at the upper layer of the zonation of lakes (epilimnion).

Surface current is caused by the blowing of the wind over the water. The wind energy is transferred from the wind to the surface of the layer (Sharma V. K., 1986; Evelyn Brown *et al*, 2001). It is important because most of the small lakes around the world are depending on surface current which is wind – induced current to influence the mixing inside the water column and transport the nutrient away (Hakanson, 1977; Rowan *et al*, 1992).

When mixing occurs, the excess nutrient is transported away by this surface current. That particular area experiences the water changes in this context is the water body near the selected cage culture area in Batang Ai Hydroelectric Dam Reservoir. The changes of water can minimize the percentage of nutrient eutrophication to occur. But it is all depend on the speed and the magnitude of the surface current either it can help to maintain the carrying capacity or to weaken the carrying capacity of the system.

2.4.2 Speed and Magnitude of Surface Current

As the intensive cage culture are planned to be done at selected area in Batang Ai Hydroelectric Dam Reservoir, the speed and magnitude of surface current study are important. It helps to determine if that area can withstand and carried all those anthropogenic input.

Before that area face the eutrophication problems that can kill all those fishes. Due to the surrounding area were tainted with algae bloom and dropped of dissolved oxygen (DO) in the water column. There were other several factors that influencing the water movements in lakes and Dam, but it will not be studied for this project.

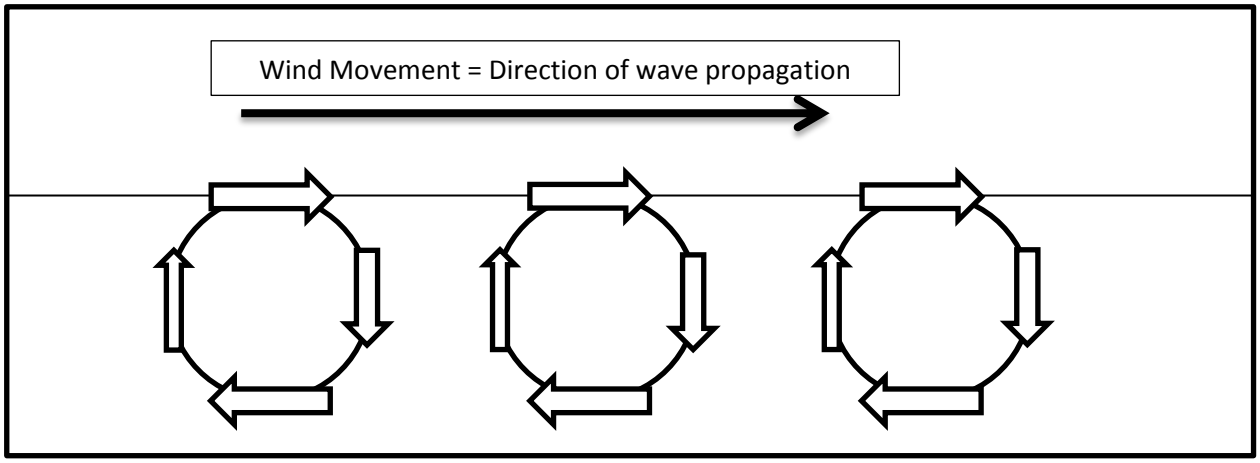

Figure 3.0 : Direction of wave propagation directly perpendicular to the wind movement that lead to water particles to make an orbital in the vertical plane which eventually give birth to the surface current (Sharma V. K., 1986).

2.5 Conductivity

Conductivity is the ability of the substance to conduct electricity (Cleophas *et al*, 2013). When the river has a high conductivity, it is indicates that there is a source of dissolved ions such as chloride, nitrate, sulphate, phosphate and other dissolved ion in the area that causes the increases in conductivity (Cleophas *et al*, 2013).

Conductivity can be as indicator for water input either from the rivers or streams. If the selected cage culture sites in Batang Ai Hydroelectric Dam Reservoir were found higher in conductivity. It means that those areas are likely to get runoff. If the value conductivity is higher, that also indicates that value of nutrient input will also be higher.

As too much of nutrient were accumulate, it will caused unwanted environmental impacts on those cage cultures area.

3.0 Materials and Methods

In this section, survey site, survey methodology and data analysis will be discussed.

3.1 Survey site

Batang Ai Hydroelectric Dam Reservoir is a concrete – face rock – fill dam in Batang Ai national Park, Sarawak. By route, almost 4 fours were utilized to get there from University Malaysia Sarawak (UNIMAS).

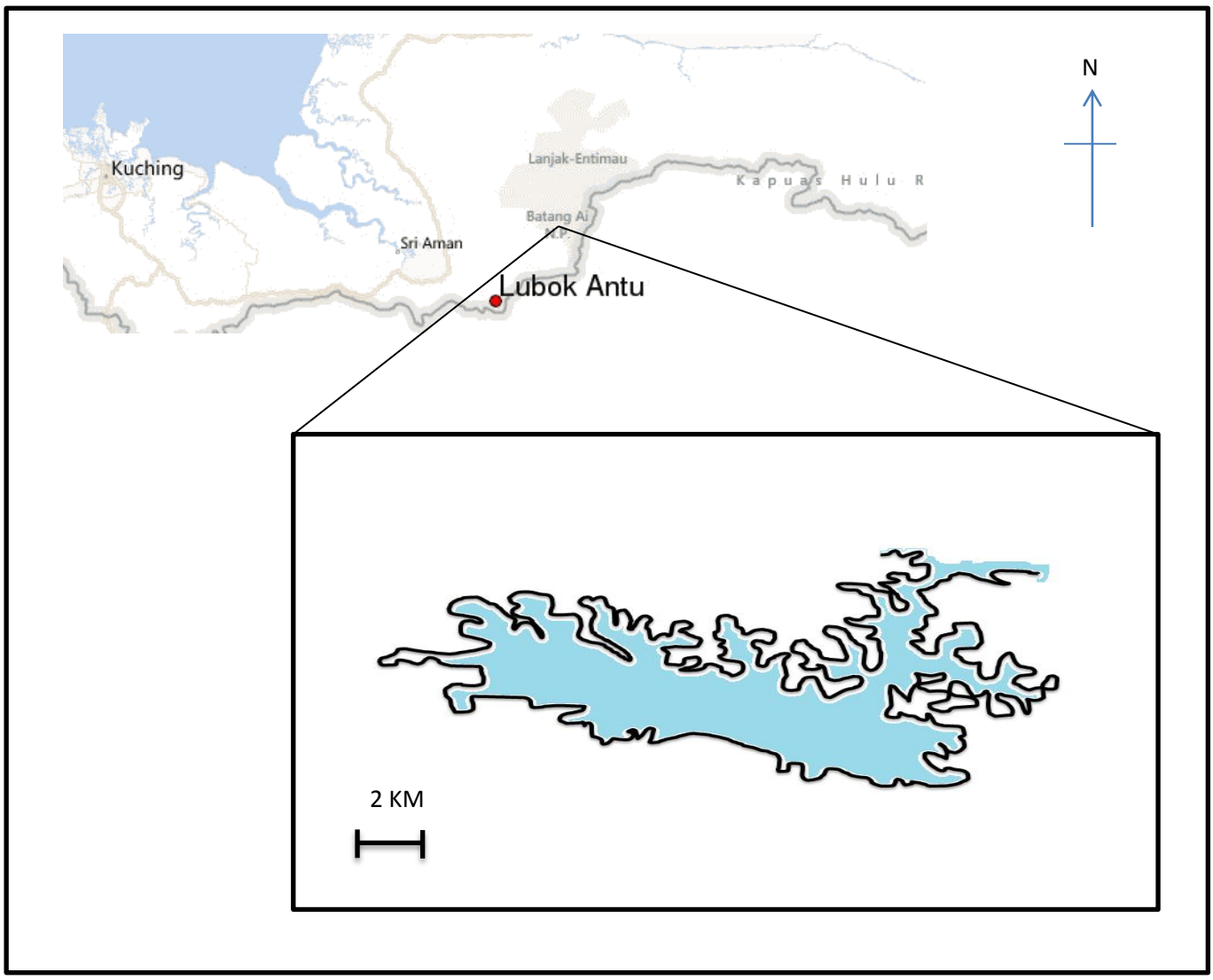

Figure 3: Map of study site (Batang Ai Hydroelectric Dam Reservoir)

3.2 Survey Methodology

In this sub – section, the precautions and measurements from deployed of the YSI CastAway CTD and Current Meter (CM) instruments are now discussed here.

3.2.1 Pre – sampling

YSI CastAway CTD

Figure 4: YSI CastAway CTD used to get the reading of Conductivity and Temperature

YSI CastAway CTD was used to get the reading of the vertical profilers of temperature and the conductivity of the selected area in Batang Ai Hydroelectric Dam Reservoir. (C) stand for conductivity, (T) temperature and (D) density. It was build - in with Global Positioning Systems (GPS). There was 24 selected stations casted to get their reading (will be discussed in next sub – topic).